PCBs and Interactions with Insecticides

by E. Paul Lichtenstein*

The effects of polychlorinated biphenyl plasticizers, like those of many other environmental chemicals ("synthetic chemicals to which man is exposed by either voluntary or involuntary means"), on biological systems are not too well understood. When research by our group at the University of Wisconsin indicated in 1969 (1) that several of the Aroclor compounds increased the toxicity of DDT and dieldrin to insects, their potential biological interaction with environmental chemicals was indicated. Since then further studies were conducted in our laboratory to investigate the effects and interactions of environmental chemicals on human cells in tissue culture by determining the toxicity of some of these chemicals on HeLa cells and skin fibroblasts (2). Aroclor 1254 (a polychlorinated biphenyl plasticizer), carbaryl, parathion, DDT, several insecticide metabolites, aspirin and caffeine were used to determine their effects on cell growth and synthesis of proteins and nucleic acids. The dosage causing a 50% inhibition in culture growth was determined, and the interaction or combined effects between these chemicals relative to their effects on protein and nucleic acid synthesis was studied. Both cell types responded nearly equally to the presence of an individual chemical. Aspirin and caffeine were 8 to 20 times less toxic than the other chemicals studied, while Arcolor 1254 was as toxic as DDT (Fig. 1). Parathion was more toxic than its metabolite paraoxon. Para-nitrophenol was as toxic as parathion. 1-Naphthol was less toxic than its parent compound carbaryl. The toxicities of DDT and DDE were dependent upon cell type. Little significant interaction on nucleic acid or protein synthesis was seen (2).

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Utilizing insects as the test objects, the biological interaction between plasticizers and some insecticides was also investigated (1). Because of the structural similarity to DDT-related compounds, 11 plasticizers were tested for their toxicological interaction with dieldrin and DDT. Many of these polychlorinated biphenyl compounds were toxic to *Drosophila melanogaster* Meigen and house flies, *Musca domestica* L., but to a lesser extent than dieldrin or DDT. Their toxicity increased with a decrease in their chlorine content. Dieldrin, DDT, or any one of the less chlorinated and more volatile plasticizers (Aroclor 1221, 1232, 1242, 1248, 1254) were toxic to both test insects (Table 1). While these polychlorinated biphenyls contain increasing amounts of chlorine, their toxicity towards the insects decreased. Dieldrin was the most toxic of the com-

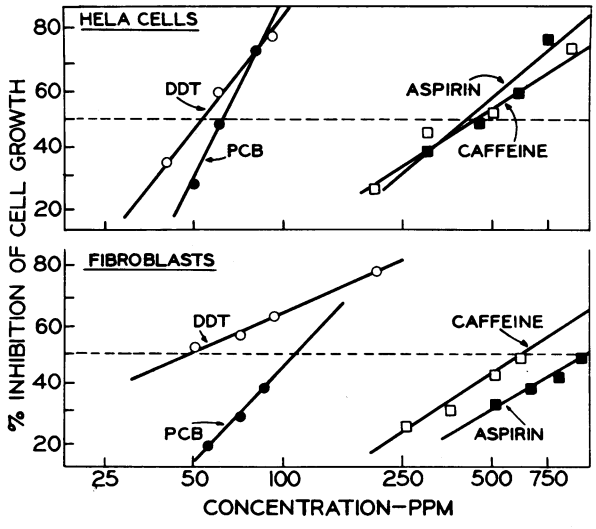

FIGURE 1. Dosage-response curves obtained after 48-hour exposure of human cell cultures to various concentrations of p,p'-DDT, Aroclor 1254 (PCB), aspirin and caffeine. (Ref. 2).

Table 1. Effect of plasticizers or insecticides on insect mortalities.

Material	D. melanogaster			House flies	
	Applied[a]	% mortality		Applied[b]	% mortality
	(μg)	24 hr	48 hr	(μg/g fly)	24 hr
None[c]		0	0		0
Dieldrin	0.1	31	84	1.0	73
p,p'-DDT	3.0	24	58	25.0	57
Aroclor 1221	200	0	0	500	17
	800	57	92	1000	43
Aroclor 1232	200	0	0	500	10
	800	35	64	1000	30
Aroclor 1242	200	0	4	500	17
	800	40	73	1000	20
Aroclor 1248	200	0	0	500	13
	800	15	45	1000	13
Aroclor 1254	2000	0	0	1000	10
Aroclor 1260	2000	0	0	1000	0

[a] Applied in 8 ml hexane to 4-oz glass jars. *D. melanogaster* exposed to dry residue.
[b] Applied topically to house flies in 2 μliter of acetone. Weight of 1 fly = 20 mg.
[c] Controls were treated with solvents only.

pounds, as measured by the percent mortality of the insects within a 24- or 48-hr exposure period. Approximately 25 and 30 times more DDT than dieldrin, and 8000 and 1000 times more plasticizers than dieldrin had to be used to obtain similar mortalities of *D. melanogaster* or of house flies, respectively, within a given time of exposure to these chemicals. The more highly chlorinated and less volatile plasticizers were nontoxic even when used at dosages of 2000 μg with *D. melanogaster* and 20 μg/fly (1000 μg/g fly) with house flies.

Table 2 summarizes the results obtained after the insects had been exposed to sublethal dosages (200 μg for *D. melanogaster*, 10 μg/house fly) of either one of the plasticizers (Aroclor 1221, 1232, 1242, 1248 or 1254) and in combination with dieldrin or DDT. Though no appreciable insect mortalities were observed with plasticizers alone, they significantly increased the toxic effects of both dieldrin and DDT. This effect was most noticeable with DDT on house flies, and differences observed were highly significant. After a 24-hr exposure period, 38% of the house flies had died after only DDT had been applied. However, all the insects were killed when DDT was applied in combination with any one of these plasticizers. The polychlorinated biphenyls also increased the toxic effect of DDT with *D. melanogaster*, but to a lesser extent. The most striking effect was observed with Aroclor 1221. Aroclor 1260, 1262, 1268, 1265, 5442 and 5460 applied with dieldrin or DDT to glass surfaces to which *D. melanogaster* were exposed reduced the toxicity of the insecticide, resulting in mortalities of 30% to none within 48 hr (1).

In particular, though, a substantial increase in the toxicity of organophosphorus insecticides to houseflies was achieved with polychlorinated biphenyl plasticizers (3). Aroclor 1248—although nontoxic by itself to house flies at dosages of 10 μg/fly—significantly increased the toxicity of the oxygen analogs of five organophosphorus insecticides after simultaneous topical application to houseflies. Both p,p'-DDT and p,p'-DDE, applied at sub-lethal dosages, also increased the mortality of houseflies due to paraoxon from 2 to 60 and 73 per cent, respectively. The polychlorinated biphenyl plasticizer, applied simultaneously with parathion, however, decreased the toxicity of parathion to houseflies but increased mortalities when applied to flies one-half hour after the application of the insecticide. The plasticizer apparently inhibited the conversion of parathion to its toxic

Table 2. Combined effects of plasticizers and insecticides on insects.

Aroclor	% mortalities of insects after exposure to		
	No insecticide	Dieldrin	p,p'-DDT
		D. melanogaster after 48 hr[a]	
None[b]	0	66±6	59±6
1221	0	87±4[c]	93±5[d]
1232	0	81±3[c]	84±6[c]
1242	5±2	77±9	83±6[c]
1248	0	72±4	77±3[c]
1254	0	10±3[c]	47±3[e]
		House flies[f] after 24 hr	
None	0	27±5	38±8
1221	4	49±3[c]	100[d]
1232	4	27±5	100[d]
1242	0	47±5[e]	98±3[d]
1248	6	58±11[e]	100[d]
1254	0	24±6	100[d]

[a] *D. melanogaster* were exposed in 4-oz glass jars to the dry durface deposit of the chemicals: plasticizers, 200μg; dieldrin, 0.1 μg; DDT, 3.0 μg.

[b] Bioassay jars without plasticizers contained 250 μg of corn oil each.

[c,d,e] Differences obtained between treatments with the insecticide only and those with insecticide plus plasticizer are significant at the c = 1%, d = 0.1%, or e = 5% level.

[f] Chemicals were applied topically in 2 μliter of acetone to houseflies: plasticizers, 500 μg/g fly; dieldrin, 0.75 μg/g fly; DDT, 15 μg/g fly. Control: only acetone was applied. Weight of 1 fly = 20 mg.

activation product, paraoxon, and the breakdown of paraoxon into nontoxic compounds. This was also indicated by the recovery of larger amounts of ^{14}C-paraoxon and smaller amounts of water soluble ^{14}C-products from flies treated simultaneously with Aroclor 1248 plus paraoxon, in comparison to those which had been treated with ^{14}C-paraoxon only. Utilizing the 10,000×G supernatant from housefly homogenates, the addition of Aroclor 1248 with ^{14}C-paraoxon in vitro also resulted—after 2 hours incubation at 30°C—in higher recoveries of ^{14}C-paraoxon and in a reduction of the appearance of water soluble ^{14}C-products. Identical results were obtained with subcellular fractions (10,000×G supernatant) from flies that had been treated with Aroclor 1248 eighteen hours before homogenate preparation. No difference was observed in the degradation of paraoxon or the appearance of water soluble products with Aroclor applied to the living flies or to the 10,000×G supernatant of homogenates from untreated flies (3).

Since plasticizers are in the environment, their potential effects on biological systems, especially in combination with other synthetic chemicals, should not be disregarded.

REFERENCES

1. Lichtenstein, E. P. et al. 1969. Biological interaction between plasticizers and insecticides. J. Econ. Entomol. 62: 761.
2. Litterst, C. L. and Lichtenstein, E. P. 1971. Effects and interactions of environmental chemicals on human cells in tissue culture. Arch. Environ. Health 22: 454.
3. Fuhremann, T. W. and Lichtenstein, E. P. 1972. Increase in the toxicity of organophosphorus insecticides to houseflies due to polychlorinated biphenyl plasticizers. Toxicol. Appl. Pharmacol. (In press).